Eurocode tools for structural detailing and connections of Single Storey Buildings

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2 main fields of expert activities:
Steel and composite steel-concrete construction
Fire engineering

Cticm was a technical partner of the STEEL project
and is member of the Steel Alliance association
Elaboration of calculation methods and software development

Contribution to national or European research projects

Teaching and professional training

Publications and Internet sites

Steel products certification (notified body)

Standardization (BNCM)

General design of new structures: buildings, bridges, towers, masts, silos...

Detailed design of new structures

Analysis of the behaviour of existing structures

Evaluation of the performances of steel products

Steel and composite constructions: cticm activities
Introduction

- Detailed design with Access Steel
- Design of members
- Design of connections
- Different types of available documents
- Other design tools to apply the Eurocodes
Typical single storey building

Rafter

Purlins

Apex connection

Beam to column connection

Column

Gable post

Base connection

Side Rail

Longitudinal stability Cross bracing

Lateral stability Portal frames

Other possible general designs

Example: cross bracings in the 4 walls and roof bracings in two directions
The current single storey buildings have generally a structural Class II according to EN 1993-1-3. Steel sheeting (roof and/or walls) generally contributes to the strength and stability of individual structural elements.

EUROPEAN STANDARD EN 1993-1-3 - October 2006
Eurocode 3 - Design of steel structures - Part 1-3: General rules
- Supplementary rules for cold-formed members and sheeting

2 - Basis of design
(6) For the design of structures made of cold formed members and sheeting a distinction should be made between “structural classes” associated with failure consequences according to EN 1990 – Annex B defined as follows:
Structural Class I: Construction where cold-formed members and sheeting are designed to contribute to the overall strength and stability of a structure;
Structural Class II: Construction where cold-formed members and sheeting are designed to contribute to the strength and stability of individual structural elements;
Structural Class III: Construction where cold-formed sheeting is used as an element that only transfers loads to the structure.
NOTE 1: During different construction stages different structural classes may be considered.
NOTE 2: For requirements for execution of sheeting see EN 1090.
DESIGN OF MEMBERS with steel
Different types of available documents

- Extracts from the standards
- Complementary information to Eurocodes (NCCI)
- Code commentaries
- Flowcharts
- Design data
- Worked examples
- “Active” worked examples

No National Annex is considered.
Complementary Information (NCCI)

- Buckling lengths of columns
- Elastic critical moment for LTB
- Elastic critical moment of cantilevers
- Critical axial force for torsional buckling modes
- Stability of mono-symmetrical uniform members
- Torsion
- Sizing guidance for columns
- …
Elastic critical moment for LTB

NCCI: Elastic critical moment for lateral torsional buckling

This NCCI gives the expression of the elastic critical moment for doubly symmetric cross-sections. Values of the factors involved in the calculation are given for common cases. For a beam under a uniformly distributed load with end moments or a concentrated load at mid-span with end moments, the values for the factors are given in graphs.

Contents

1. General 2
2. Method for doubly symmetric sections 2
3. $C_1$ and $C_2$ factors 4
4. References 12
**LTBeam software:**
Calculation of the elastic critical moment

Available on www.cticm.com
Torsional and flexural-torsional buckling

NCCI: Critical axial load for torsional and flexural torsional buckling modes

This NCCI gives the expressions for the critical axial load for the torsional buckling mode and the flexural-torsional buckling mode.

Contents

1. General ........................................ 2
2. Torsional buckling .......................... 2
3. Flexural-torsional buckling ............... 3
4. References ..................................... 4
Design data : Classification of cross-sections

Data: Section classification tables for European hot rolled beam profiles (IPE and HE profiles)

This NCCI contains tables giving the section classification of IPE and HE profiles, according to the Eurocode rules. Classifications are given for pure bending about both axes and for bending with axial compression. The tables cover steel grades S235, S275, S355 and S460.

Contents
1. General 2
2. Key to tables 2
3. Examples of the use of the tables 3
4. Tables for IPE profiles 4
5. Tables for HE-profiles 8
6. References 12
Flowcharts …for designers

• Design of columns
• Beam under uniform loading
• Design of a wind transverse girder
• Buckling verification of non-uniform members
• Design of cold formed members
• …
Design of columns

Flow Chart: Design of non-composite columns

This flow chart presents the simple equivalent column approach for non-composite columns. It uses the non-dimensional member slenderness and derives an appropriate reduction curve to be applied to the cross sectional resistance to axial compression. The chart indicates that where the column is also subjected to bending, the interaction between compression and buckling should be checked.

1. Start
2. Design loading
   \( N_{c}, N_{	ext{ext}} \) and
3. Design guidance on choice of section - EN 1993-1-1
   \( \text{EN 1993-1-1} \)

4. Choose a column section
   \( A_{	ext{bend}} \)

5. Classify cross section
   \( N_{c} \text{ or } N_{	ext{ext}} \)

6. Determine ultimate cross section properties (evaluate shift \( x_{C} \) if any) and the resulting additional moment

7. Determine design resistance of cross section
   \( N_{c,\text{des}} = A_{	ext{eff}} f_{x} / N_{c} \)

8. Determine design resistance of cross section
   \( N_{c,\text{des}} = A_{	ext{eff}} f_{x} / N_{c} \)
Worked examples

- Buckling resistance of a column
- Simply supported beam, laterally restrained
- Simply supported beam, unrestrained
- Design of a purlin (hot rolled profile)
- Design of cold formed members
- Elastic analysis of a portal frame
- ...
Elastic analysis of a portal frame

Example: Elastic analysis of a single bay portal frame

A single bay portal frame made of rolled profiles is designed according to EN 1993-1-1. This worked example includes the elastic analysis of the frame using first order theory, and all the verifications of the members under ULS combinations.
“Active” worked examples

Variable loading

\[ Q_v = w_{max} \times F_{imp} = 6.25 \text{ kNm} \]

**ULS Combination**

Total ULS load

\[ P_{ULS} = Q_v \times \gamma_0 + Q_o \times \gamma_0 = 22.10 \text{ kNm} \]

**Moment diagram**

Maximal moment at midspan

\[ M_{max} = 0.125 \times P_{ULS} \times L^2 = 89.77 \text{ kNm} \]

**Shear force diagram**

Maximal shear force at supports

\[ V_{max} = 0.5 \times P_{ULS} \times L = 61.00 \text{ kN} \]
Calculation of steel beams according EN 1993 and EN 1994

ArcelorMittal Beams Calculator
ArcelorMittal Beams Calculator

- Composite and non composite beams
- ULS and SLS calculations
- LTB verification based on $M_{cr}$ calculated by the LTBeam engine
- Detailed calculation sheet
- Available on the web site

www.arcelormittal.com/sections
DESIGN OF CONNECTIONS
For connection calculations, reference is made to EN 1998-1-8 and its national annex
List of contents of EN 1993-1-8

1 - Introduction
2 - Basis of design
3 - Connections made with bolts, rivets or pins
4 - Welded connections
5 - Analysis, classification and modelling
6 - Structural joints connecting H or I sections
7 - Hollow section joints
All types of connections are covered by application or interpretation of EN 1993-1-8.

The general principle to determine the resistance and stiffness of any connection is to consider the connection as a series of components. The resistance of the connection is obtained from the failure modes of each component.

But a liable calculation is not sufficient to ensure the good behaviour of a connection; a careful execution is also necessary !!! See EN 1090-2.
Connections of the main structure of a typical single storey building

- Eave connection
- Opt. Mezzanine floor beam connection
- Apex connection
- Column base connection
- Opt. Crane bracket
- Connection of a bracing on a gusset plate
In general cases:

- **Apex connection**: RIGID CONNECTION – CONNECTION BY BOLTED END PLATES – CHAPTER 6 OF EN 1993-1-8 – NCCI – FLOW CHART (+ ASCAP)
- **Eave connection**: RIGID CONNECTION – CONNECTION BY BOLTED RAFTER END PLATE – CHAPTER 6 OF EN 1993-1-8 – NCCI (+ ASCAP)
- **Column base connection**: EITHER PINNED OR RIGID CONNECTION (RIGID WHERE DEFORMATIONS HAVE TO BE LIMITED: PRESENCE OF A CRANE…) – CHAPTER 6 OF EN 1993-1-8 (6.2.8 – 6.3.4) – FLOW CHART (PINNED)
- **Connection of a bracing on a gusset plate**: PINNED CONNECTION – CHAPTER 3 OF EN 1993-1-8 - EXAMPLE
- **Crane bracket**: RIGID CONNECTION – EITHER WELDED CONNECTION (CHAPTER 4 OF EN 1993-1-8) OR CONNECTION BY BOLTED BRACKET END PLATE (CHAPTER 6)
- **Mezzanine floor beam connection**: PINNED CONNECTION – EITHER BY 2 BOLTED ANGLES, OR BY FIN PLATE (NCCI – FLOW CHART – EXAMPLE), OR BY THIN PARTIAL END PLATE (NCCI – FLOW CHART)
- (+ ASCAP FOR CONNECTIONS BY 2 BOLTED ANGLES)
**NCCCI (Non Contradictory Complementary Information)**

- Design of portal frame eaves connections
- Design of portal frame apex connections
- Design model for non bearing column splices
- Design of bearing column splices
- Design model for splices in structural hollow sections
- Column splices not requiring full continuity of stiffness
- Column base stiffness for global analysis
- Design of a notched section at the end of a beam
NCCI

- Design model for simple column bases
- Design of simple column bases with shear nubs
- Design of fixed column bases
- Tying resistance of a fin plate connection
- Tying resistance of a simple end plate connection
- Shear resistance of a fin plate connection
- Shear resistance of a simple end plate connection
- Initial sizing of fin plate connections
- Initial sizing of simple end plate connections
- Initial sizing of non bearing column splices
NCCI: Design of portal frame apex connections

This NCCI provides information on the design method for a bolted apex moment connection. It includes several simplifications which are explained throughout the document, to obtain simpler but conservative calculations. This NCCI references repeatedly to SN041 to benefit from the common approach to design apex and eaves connections and therefore only presents those contents specific for apex.

Contents

1. Design model
2. Parameters
3. Weld design
4. Potential resistances of bolt rows in the tension zone
5. Assessment of the compression zone
6. Force distribution in bolt rows
7. Assessment of the shear resistance
8. Limits of application
9. Background
Resources

Flow charts

- Portal frame eaves connection
- Portal frame apex connection
- Simple end plate connection
- Fin plate connection
- Design model for non bearing column splices
- Design of a chord splice in structural hollow sections
Flow charts

- Design model for welded joints in trusses using hollow sections
- Design resistance of screwed connections of cold-formed members
- Design of a column base under axial load
- Pinned column base connection in portal frames
- Fixed column bases
Design of a portal frame apex connection

Flow chart: Portal frame apex connection

This chart sets out the process for verifying the adequacy of a bolted end plate connection for a portal frame. The resistances in the tension and the compression zones are determined before the design moment resistance of the joint is established. The vertical shear resistance is also determined.
Examples

- Portal frame eaves moment connection
- End plate beam-to-column flange simple connection
- Fin plate beam-to-column flange connection
- Column splice – non bearing splice
- Column base connection under axial compression
Examples

• Design resistance of a screwed connection of cold-formed members
• Bolted connection of an angle brace in tension to a gusset plate
• Fin plate beam-to-column-flange connection
• Truss/post end connection
Example: Bolted connection of an angle brace in tension to a gusset plate

Figure 1.1  Detail of the bolted connection: plan and section view
Other tools than Access Steel also provide resources to calculate the resistance and stiffness of connections according to Eurocode EN 1993-1-8.

An example of such tools is the tables ASCAP developed by the cticm and giving the capacity of standardized connections.

For different types of connections, paper tables are edited in a book that also contains a CD with extended tables and a research engine. In the next months, the software used to produce ASCAP tables will be available on cticm internet site www.steelbizfrance.com
Assemblages de continuité de poutres réalisés par platines d’about

Collection « les guides Ascap »
The first ASCAP book concerns beam-to-beam connections (bolted end plates). Paper tables give the capacity of 400 standardized connections, and the associated CD gives the capacity of 7000 connections.

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CONCLUSION

- Various tools are now available to apply the Eurocodes
- Access Steel is the most important European web site for the application of Eurocodes to steel structures
- Access Steel provides different types of information for common single storey buildings (NCCI, Flowcharts, examples...).
Thank you for your attention